

Different evolutionary stages in the Miogypsinidae from Sardinia

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SUMMARY — Biometric analysis of *Miogypsina* assemblages from two Marmilla outcrops (central-southern Sardinia), allows to emphasize that the two assemblages show a different evolutionary stages in the process of nepionic acceleration, referable to the species *Miogypsina* (*Miogypsinoides*) *bantamensis* Tan Sin Hok and *M.* (*Miogypsina*) *intermedia* Drooger, respectively.

These species appear clearly spaced, both phylogenetically and stratigraphically; their identification, together with others mentioned in literature, allows one to suppose in a preliminary way that in Sardinia the development of a large part of the major phyletic lineage of Mediterranean *Miogypsinids* took place.

The fragmentary record of the evolutionary development of the Sardinian *Miogypsinidae* could be in relationship, beside the scarcity of the available data, with spatially variable ecological conditions suitable for their settling, during the Sardinian Oligo-Miocene reefing process. On the other hand, the absence of representatives of the end members of the Mediterranean *Miogypsinidae* lineage which are recorded in southern Spain, Morocco and Algeria, if confirmed, could be connected with a faunistic break consequent to the opening of the Balearic Basin in the Early Miocene.

The sample with *M.* (*Miogypsinoides*) *bantamensis* is referred to the lowest part of the N4 Zone of Blow (1969), while the planktonic foraminiferal content associated with *M.* (*M.*) *intermedia* (*Globigerinoides* *altiaperturus*-*Catapsydrax* *dissimilis* Subzone) seems to confirm, with a greater detail, the correlations already known in literature.

RIASSUNTO — [Diversi stadi evolutivi nelle miogypsine della Sardegna] — L'analisi biometrica delle *Miogypsine* provenienti da due affioramenti della Marmilla (Sardegna centro-meridionale), ha permesso di mettere in evidenza un netto scarto tra i rispettivi livelli raggiunti nel processo di accelerazione nepionica, riferibili alle specie *Miogypsina* (*Miogypsinoides*) *bantamensis* Tan Sin Hok e *M.* (*Miogypsina*) *intermedia* Drooger.

Queste specie risultano nettamente distanziate, sia filogeneticamente, sia stratigraficamente; il loro riconoscimento, unitamente ad altre segnalazioni in letteratura, permette di supporre in via preliminare che in Sardegna abbia potuto avere luogo lo sviluppo di gran parte della linea filetica principale delle *Miogypsine* mediterranee.

L'attuale frammentarietà con cui si presenta il riconoscimento dello sviluppo evolutivo delle *Miogypsinidae* in Sardegna, può essere messa in relazione, oltre che con la scarsità di dati finora disponibili, anche con la discontinuità nella distribuzione di condizioni ecologiche adatte al loro insediamento, durante il processo di rifting oligo-miocenico sardo; l'assenza invece dei rappresentanti della fase terminale della filogenesi delle *Miogypsinidae* mediterranee, presenti invece nella Spagna meridionale, in Marocco e Algeria, se confermata, potrebbe essere messa in relazione con un break faunistico conseguente all'apertura del Bacino Balearico nel Miocene inferiore.

INTRODUCTION

Biometric analyses on *Miogypsinidae* from Sardinia were previously performed only on 6 assemblages collected stratigraphically in a sequence outcropping at Capo Funtanazza, near Marina di Montevecchio (Cagliari) by Smit in 1974. This Author referred all the six assemblages to one species, *Miogypsina* (*Miogyp-*

sina) *intermedia* Drooger, based on the very advanced evolutionary stages of their nepionts.

Successively, Cherchi & Montadert (1982a, b) recorded in Miocene strata from the Isili and Mandas areas, the species *M.* (*Miogypsinoides*) *bantamensis* Tan Sin Hok, *M.* (*Miogypsinoides*) *complanata* Schlumberger, *M.* (*Miogypsina*) cf. *gunteri* Cole, recognised on a typological basis. This new stock is the first indication

that in Sardinian Miocene forms at a nepionic stage less advanced than that recognised by Smit also existed and, as already known from several localities of the Mediterranean area, the main Miogypsinidae lineage may be represented also in Sardinia.

Aim of the present paper is to add a few more informations on Sardinian Miogypsinidae, based on the new findings from the Marmilla area.

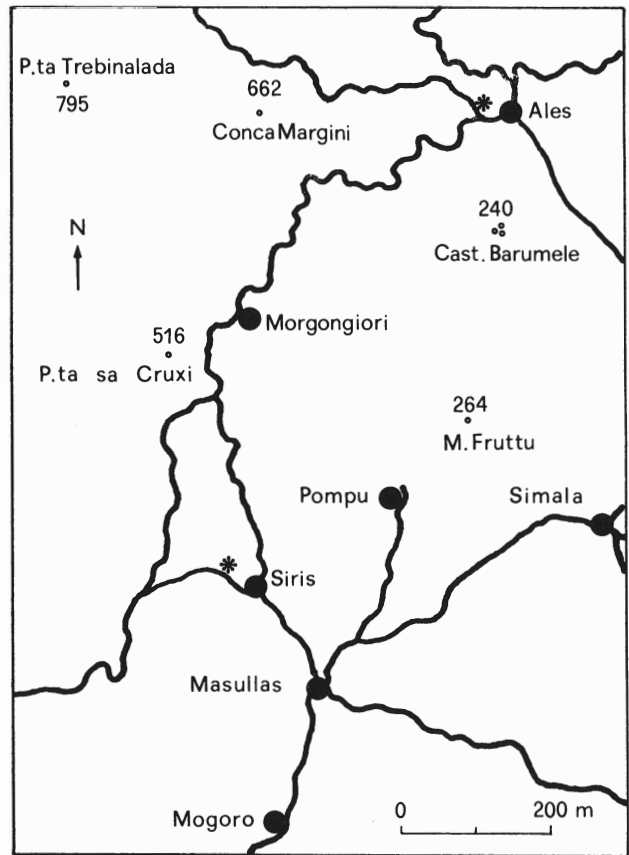
LOCALITIES AND SAMPLES

The samples, object of the present study, come from the Marmilla area (Central-Southern Sardinia). The location of their outcrops is reported in Text-fig. 1. For a general geological and stratigraphical outline of the Tertiary basin of Sardinia, the reader can refer to Boccaletti & Guazzone (1974), Cherchi (1974, 1979), Cherchi & Montadert (1982a, b) and to the Guide Book of the 19th European Micropal. Colloquium, 1985.

Sample Si-a — From sediments outcropping along the municipal road from the Siris village to the State Road 442, just before km 40. The outcrop is located at Preula (Siris).

A calcareous-organogenic lens overlies a complex volcanic basement (pillow-lavas, hyaloclastites, and volcanic sandstones); the same lens is laterally digitated with several apophyses tapering as far as they disappear within marly-sandy-tuffitic sediments. The sequence is disturbed by several little faults fracturing the calcareous levels, that sometimes appear as blocks protruding from the marly-sandy matrix.

The miogypsinids occur in the calcarenitic and marly-calcareous layers overlaying the volcanics; Miogypsinidae are rather rare: only 100 specimens were recovered processing 2 kg of sediments. The preservation of the test's internal structures is fairly good, while their outer surfaces are frequently eroded especially in the apical portion.



Text-fig. 1 - Schematic map showing the location of sample Si-a, Siris section, and AC 5, Ales section.

The associated larger foraminifera are rare specimens of *Planoperculina* sp. No specimens of *Lepidocyclina* have been found.

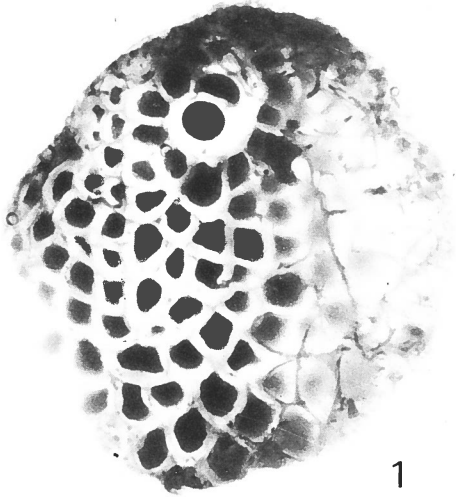
40 entire specimens suitable for biometrical study were randomly picked from the assemblage.

Sample AC 5 — From the sequence outcropping near Ales village, along the municipal road leading to M. Conca Margine (M. Arci).

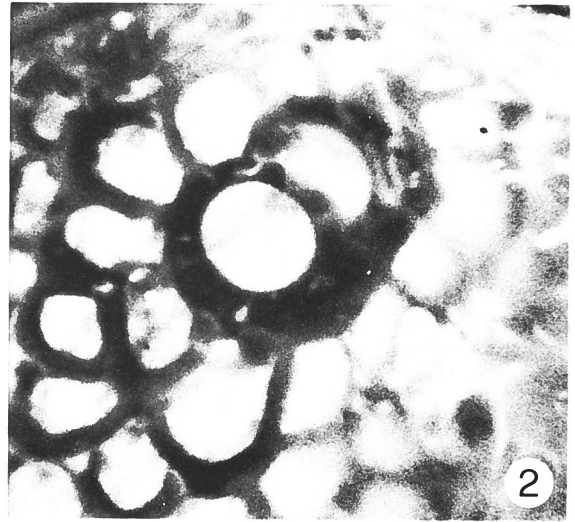
EXPLANATION OF PLATE 1

Miogypsina (Miogypsinoides) bantamensis Tan Sin Hok. Sample Si-a, Siris section, Sardinia.

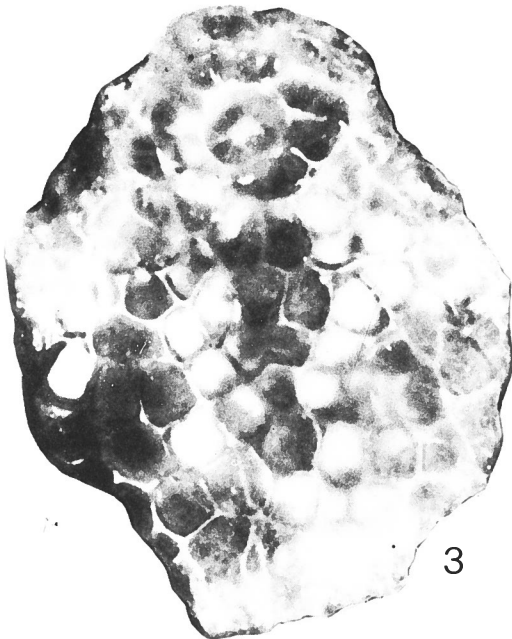
- Figs. 1, 4 - Median sections of specimens with a number of nepionic chambers near the \bar{X} value; 1) Specimen no. 9, x 36; on the right, traces of the intraseptal canal system are visible; 4) Specimen no. 16, x 36; transmitted light.
- Fig. 2 - Detail of the embryonic-nepionic stage of the same specimen as in fig. 1, showing spiral chambers surrounding the deuterocoel and originating from the first chamber of the main spiral surrounding the protoconch; reflected light, x 100.
- Fig. 3 - Median section of a specimen showing the patterns of the intraseptal canal system. Specimen no. 5, x 60; reflected light.
- Fig. 4 - Detail of an embryonic-nepionic stage, $X = 12$. Specimen no. 40, x 100; transmitted light.
- Fig. 6 - Detail of the embryonic-nepionic stage of a specimen in which the two nepionic spirals cross above the deuterocoel. Specimen no. 23, x 80; transmitted light.



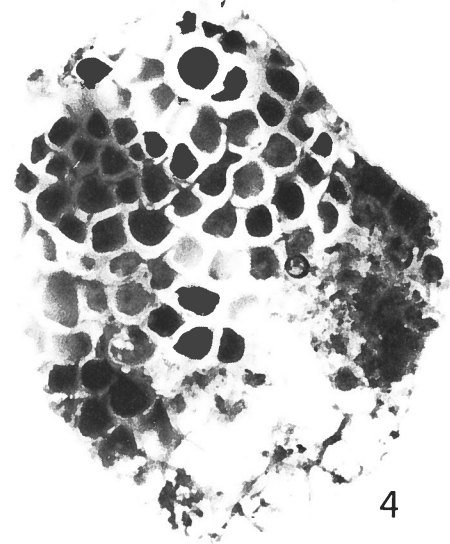
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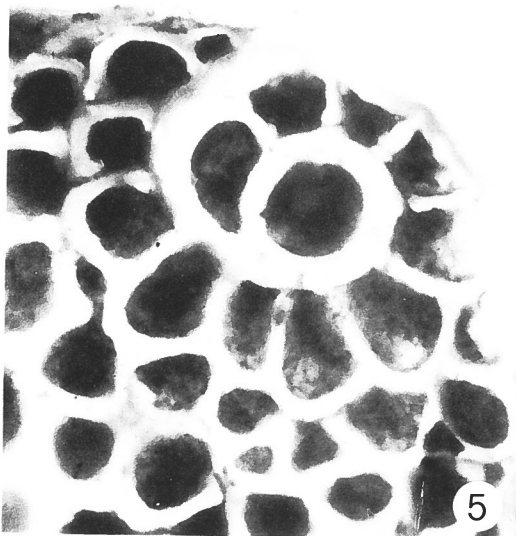
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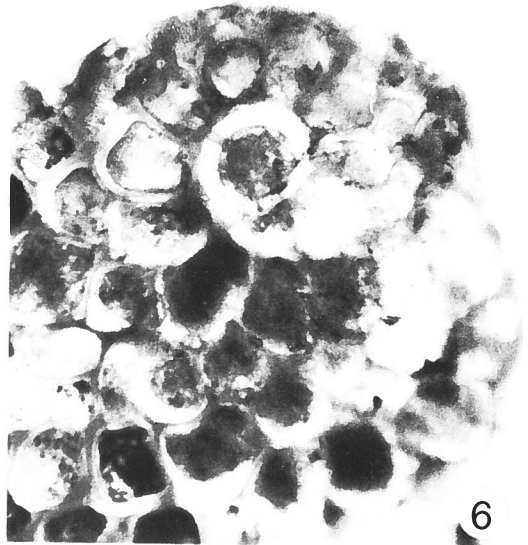
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The sediment is calcarenitic (turbidite) and intercalated within pelagic marls; the Miogypsiniidae are less common than in sample Si-a. The state of preservation of the tests is good.

The associated larger Foraminifera are very rare specimens of *Planoperculina* sp. and of *Lepidocyclina*. These last forms are too few (N=8) for a reliable biometric study. However, all the embryonic apparatuses display a high degree of enclosure of the protoconch by the deuterococonch (Pl. 2, fig. 6) (Factor A=45-52%). The values of Factor A allow to attribute in a preliminary way the Marmilla specimens to *Lepidocyclina* (*Nephrolepidina*) cf. *tournoueri* Lemoine & R. Douvillé, a species the range of which in literature spans the interval corresponding to the Early Miocene Zones N5-N7 of Blow (1969) (De Mulder, 1975).

Planktonic Foraminifera from the same sections were studied by Iaccarino *et al.* (this vol.). They are attributable to the *Globigerinoides altiapertura-Catapsydrax dissimilis* Subzone.

Calcareous Nannofossils would be indicative of Zone NN1 (Lower part) (Guide Book of the 19th European Micropal. Colloquium). Fifty-four specimens of Miogypsiniids randomly picked from this second assemblage were suitable for biometric study.

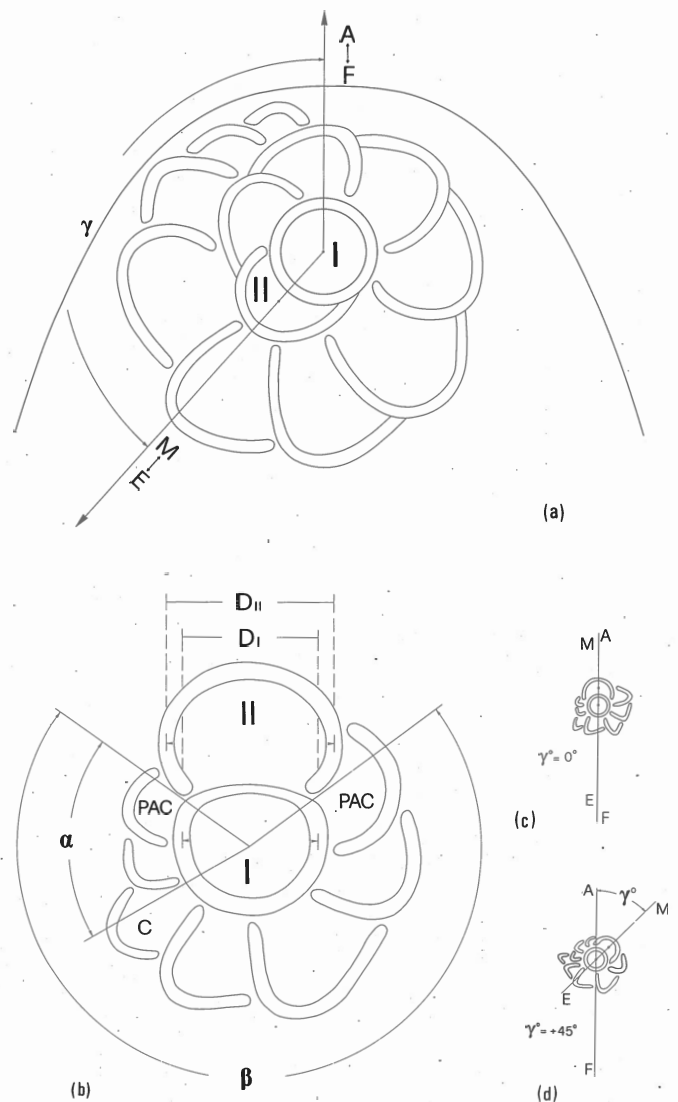
METHODS OF INVESTIGATION

A schematic drawing of the embryonic and nepionic chambers of Miogypsiniidae in equatorial section is shown in Text-fig. 2. In the same drawing the following parameters and measurements are indicated:

- X = total number of the chambers of the nepionic spiral around the protoconch (I) and the deuterococonch (II); the two embryonic chambers are excluded from the calculation (Text-fig. 2a).
- X_I = In more evolved specimens two primary auxiliary chambers (PAC) are present, from which develop two spirals around the protoconch (Text-fig. 2b); in such case, the number of chambers counted are from the longest spiral or, in the case of equally long spirals, counting concerns the chambers from the spiral developed from the largest PAC; the symmetric chamber (c in Text-fig. 2b), resting on the last chamber of both nepionic spirals around the protoconch, was included in the count as 1/2.
- X_{II} = Count similar to the previous one but including a value of 1 for the symmetric chamber.
- V = Degree of symmetry of the spirals around the protoconch, deduced according to the formula

$$V = \frac{\alpha}{\beta} \cdot 200, \text{ in which } \alpha \text{ is the angle made}$$

by the shortest spiral and β is the angle made by both spirals around the protoconch. V shows values varying from 0, when the second PAC is absent, to a maximum of 100, when the two spirals around the protoconch have an equal length.



Text-fig. 2 - Schematic drawing showing the methods of counting and measuring the internal features in horizontally sectioned embryonic-nepionic stage of primitive (2a) and more developed (2b) *Miogypsina* specimens. I = protoconch; II = deuterococonch; PAC = primary auxiliary chambers; c = symmetric chamber; AF = apical-frontal line; ME = medio-embryonic line; γ = angle between ME and AF lines; D_I = diameter of the protoconch; D_{II} = diameter of the deuterococonch; α = angle made by the shortest spiral around the protoconch; β = angle made by both spirals around the protoconch.

γ = Angle included between the medio-embryonic line (ME) passing through the centre of both embryonic chambers and the apical-frontal line (AF), passing between the apex and half of the frontal margin of the test as shown in Text-fig. 2a, c, d; the values of this parameter vary from positive to negative, with $\gamma = 0^\circ$ when the two lines ME and AF coincide. For further information the reader could refer to Amato & Drooger (1969).

D_1 = Diameter of the protoconch, including the half-thickness of the walls, perpendicularly to the medio-embryonic line.

The angular measurements were carried out on photographic enlargements (x 180 for V, x 90 for γ).

The measuring methods are those introduced and successively elaborated by Drooger (1952, 1953, 1954a, b, 1956a, b, 1960, etc.).

Numerous works have confirmed the validity of this method in correlating the phylogeny of the Miogypsinidae with the stratigraphic scale (Drooger, 1963, 1966; Drooger & Freudenthal, 1964; Drooger *et al.*, 1955; Souaya, 1961; Raju, 1974; De Mulder, 1975; De Bock, 1976, 1977).

Although there is only one work by Smit (1974) concerning the Miogypsinidae from Sardinia, there is a large number of data related to the *Miogypsina* assemblages from other outcrops in Italy (Drooger, 1954a; Selli, 1957; Drooger & Socin, 1959; Pieroni, 1965; Vervloet, 1966; Serpagli & Sirotti, 1966, 1967; Ferrero, 1968; Sgrosso & Torre, 1968; Schüttenhelm, 1976; Schiavinotto, 1979, 1984).

RESULTS

The rapid, cladistic (according to Drooger, 1984, pag. 116) development of Miogypsinidae is regulated by the principle of nepionic acceleration introduced by Tan Sin Hok (1936a, b; 1937a, b): the primitive forms referable to the subgenus *Miogypsinoides* appear to be provided with a long spiral of nepionic chambers around the two embryonic chambers; through time the mean number of the chambers of such spirals is progressively reduced in the populations.

Parameter	N	Range	M	SD	SD _M
X	40	10 - 17	12.60	1.67	0.26
γ	40	-36 - -233	-139.70	45.89	7.25
D_1	40	92 - 190	146.17	24.67	3.90

Tab. 1 - Numerical data of embryonic apparatus of *Miogypsina* (*Miogypsinoides*) *bantamensis* Tan Sin Hok. Sample Si-a, Siris section, Sardinia.

For *Miogypsina* s.s. the evolution initially occurs in a way similar to that of *Miogypsinoides*, but in the more evolved forms there is the appearance of two primary auxiliary chambers (PAC) from which develop two nepionic spirals around the protoconch; through time, from a population with a clearly asymmetric spirals, it passes, through a progressive reduction of the mean number of the chambers of the longest spiral, to a population with an increasing symmetry between the two spirals (Drooger, 1963).

Observational results on the Si-a and AC 5 assemblages well agree with the evolutionary succession of the Mediterranean Miogypsinidae as supported by measurements on the embryonic and nepionic apparatuses as summarised in Tabs. 1 and 2.

Parameter	N	Range	M	SD	SD _M
X _I	52	3.5 - 7	4.72	0.84	0.11
X _{II}	52	4 - 7	5.21	0.82	0.11
V	52	23.48 - 93.86	54.93	17.55	2.43
γ	54	+5 - +85	+32.35	17.57	2.43
D_1	54	110 - 234	177.25	27.03	3.67

Tab. 2 - Numerical data of embryonic apparatus of *Miogypsina* (*Miogypsina*) *intermedia* Drooger. Sample AC 5, Ales section, Sardinia.

SPECIFIC ATTRIBUTION

In the Si-a sample the mean values of the internal parameters (Tab. 1) show a rather primitive evolutionary stage of the *Miogypsina* assemblage. All the examined specimens possess only one nepionic spiral with consequent $\bar{V} = 0$, while the value of the γ angle appears constantly negative. Such internal characteristics appear similar to those characterizing assemblages in which representatives of *Miogypsinoides* and more primitive forms of *Miogypsina* s.s., such as *M. (M.) basraensis* Bronnimann and *M. (M.) gunteri* Cole (De Bock, 1976) are associated.

In most of the studied specimens, lateral chambers are missing; in few others, generally poorly preserved, reliable observations during the preparation of oriented equatorial sections were prevented, so the absence or presence of lateral chambers could not be ascertained; consequently the subgeneric attribution of the latter specimens appeared not defined.

Moreover, the lateral chambers in a primitive species of *Miogypsina* s.s. as *M. (M.) basraensis* could appear as small cavities difficult to recognise when the material is not perfectly preserved (De Bock, 1976, p. 46, fig. 30).

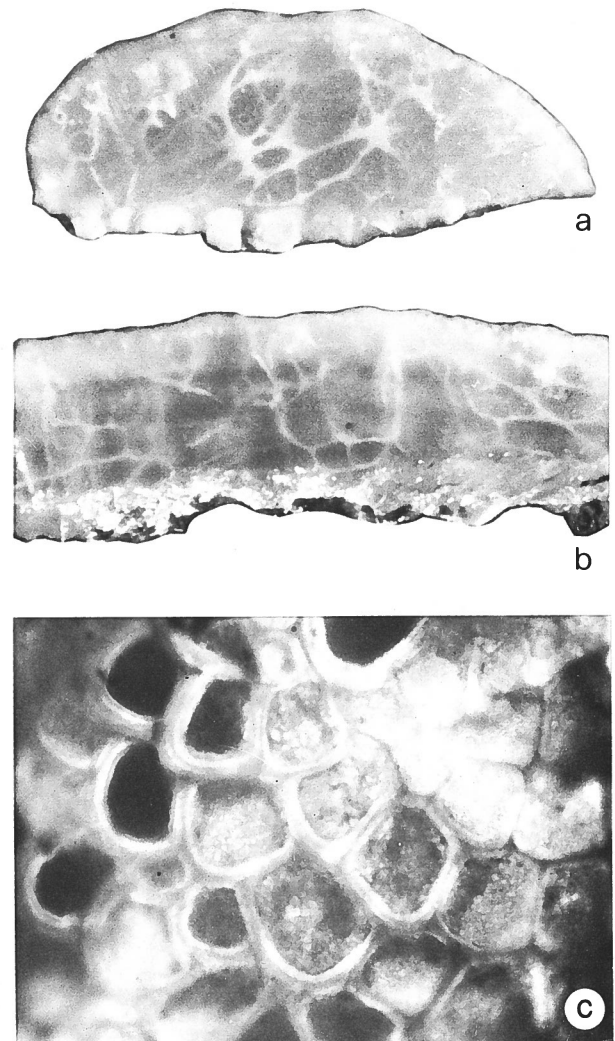
According to De Bock (1976), the presence of a canal system formed by the combination toothplate-septal flap - primary wall would be used in differentiating the subgenus *Miogypsinoïdes* from *Miogypsina* s.s. To look for such a structure (Text-fig. 3a, b, c; Pl. 1, fig. 3) appeared useful for establishing to what subgenus could be attributed the specimens in which the presence or absence of lateral chambers was not detected. The canal system could be easily observed at the optical microscope in specimens splitted into two halves by a slight pressure exerted along the peripheral margin.

Specimens in equatorial sections (Pl. 1, fig. 3; text-fig. 3c), show clear cavities completely filled with a whitish material (probably calcite) which makes visible the negative model of the inner structures. The presence of an intraseptal, of a lateral, and vertical canal system (Text-fig. 3a, b) seems to be proven. What observed in the specimens from Si-a sample is consistent with the canal system shown by De Bock (1976).

After such observations, the presence of representatives of *Miogypsina* s.s. must be excluded and Si-a population must be considered homogeneous. The mean value of X between 13 and 10 associated with a negative mean value of γ is then diagnostic for attributing the Si-a assemblage to *Miogypsina* (*Miogypsinoïdes*) *bantamensis* Tan Sin Hok (Drooger, 1963, pp. 315-349; De Bock, 1976, p. 15).

The histograms of Text-fig. 4 show a bimodal distribution of X as well as of γ , while on the contrary the distribution of D_1 is unimodal. It seems very likely that these types of distribution are due to an artifact related to poor sampling. Many specimens, having the last portion of the nepionic stage broken, were in fact excluded from counting and measurements.

In a preliminary comparison between this population and forms which in the literature were attributed to the same specific unit, it can be observed that the mean value of $X = 12.60$, calculated in the Si-a po-



Text-fig. 3 - Canal system in *Miogypsina* (*Miogypsinoïdes*) *bantamensis* Tan Sin Hok, Sample Si-a. a) and b) Ventral sides showing intersections between vertical and lateral canal systems, observed at reflected light: a) vertical section, slightly oblique, specimen no. 41, x 50. b) detail of a vertical section, specimen no. 42, x 68. c) Intraseptal canal system in a median section, observed at transmitted light, specimen no. 12, x 105.

EXPLANATION OF PLATE 2

Miogypsina (*Miogypsina*) *intermedia* Drooger, Sample AC 5, Ales section, Sardinia.

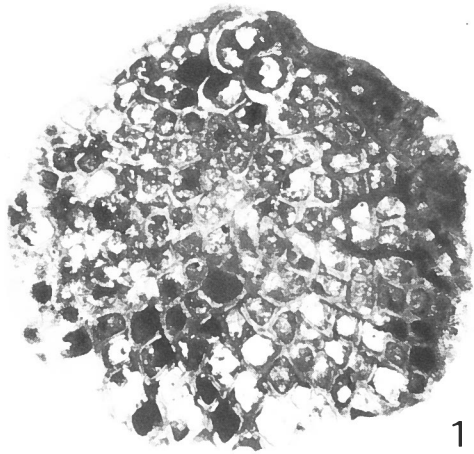
Figs. 1, 2 - Median sections; 1) specimen no. 49, x 40; 2) specimen no. 15, x 34.

Fig. 3 - Detail of the first chambers of the same specimen as in fig. 2, x 130, showing a primitive stage of the nepionic development.

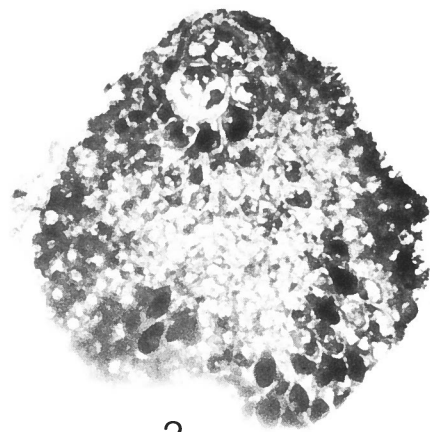
Fig. 4 - Detail of the first chambers of a specimen at an intermediate stage of the nepionic development; specimen no. 46, x 125.

Fig. 5 - Detail of the first chambers of a specimen at a highly developed nepionic stage; specimen no. 19, x 125.

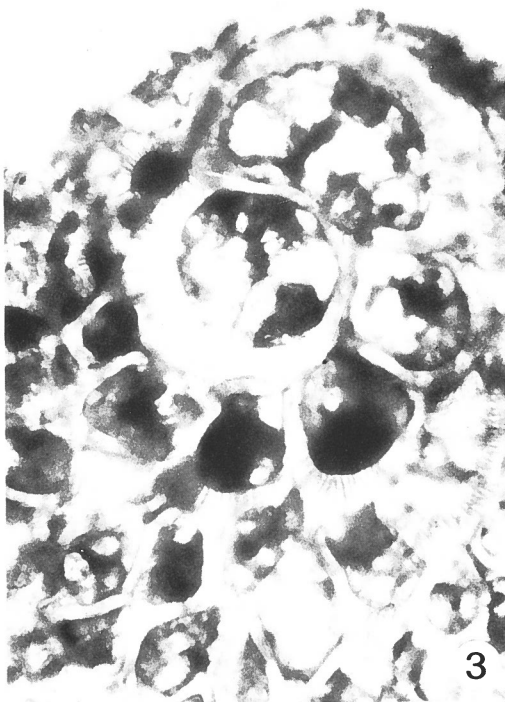
Fig. 6 - Embryonic-nepionic chambers in *Lepidocyclus* (*Nephrolepidina*) cf. *tournoueri* Lemoine & R. Douvill ; specimen no. N7, x 80.



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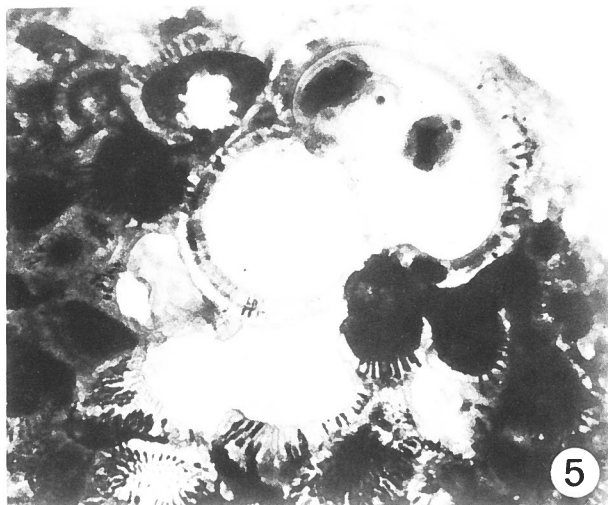
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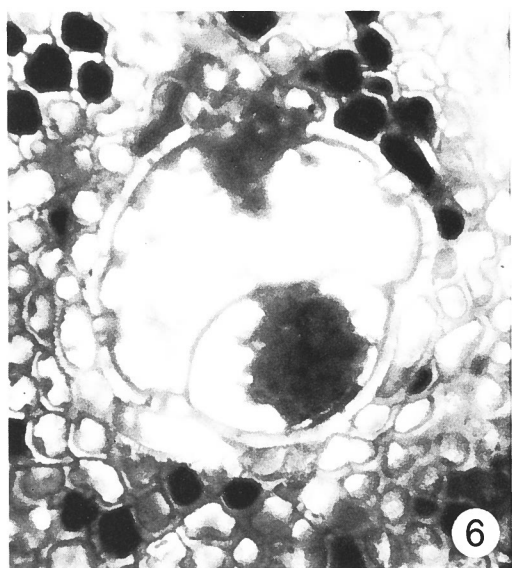
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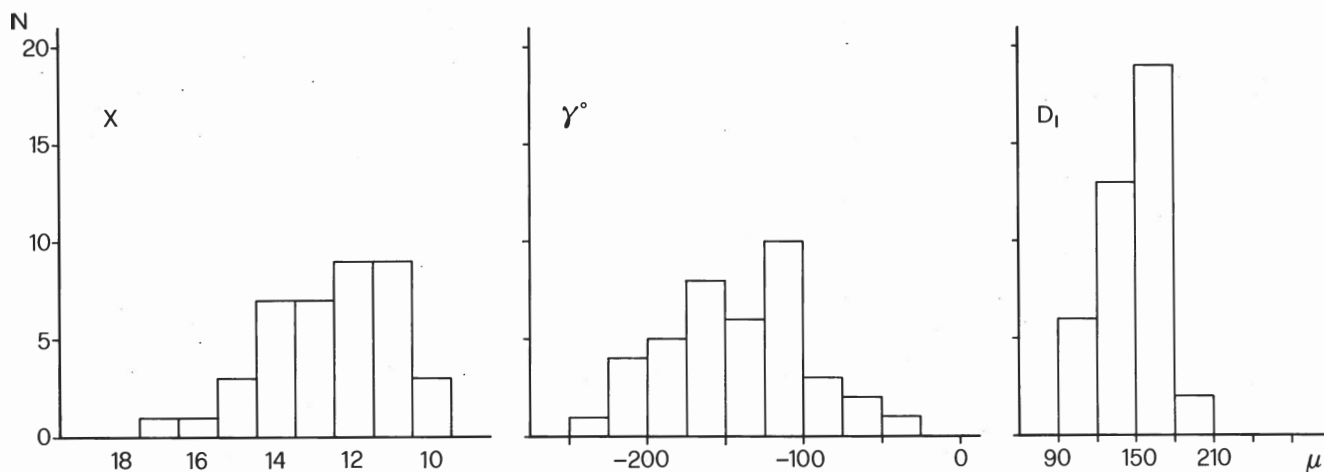
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Text-fig. 4 - Histograms showing the distributions of X , γ , and D_1 values per number of specimens of *Miogypsina* (*Miogypsinoidea*) *bantamensis* Tan Sin Hok, Sample Si-a, Siris section.

pulation, represents an evolutionary stage among the most primitive ones of *Miogypsina* (*Miogypsinoidea*) *bantamensis*. It appears even more primitive than those observed by De Bock (1976) in the material from France, as in the M 81 samples (Cap de Nautes), FR 1117, FR 1118 and FR 1120 (Estoti), and M 51 (Calanque de Petit Nid); in the latter cases the mean value of the γ angle and of D_1 also show broad analogies with those of sample Si-a.

Moreover, populations in which mean values of X are close to $X = 11$ or between 11 and 10 (samples M 61, Anse dei Bano; FR 1119, Estoti) result very close to the transition to *M. (Miogypsinoidea) dehaartii* Van der Vlerk.

A comparison with the assemblages from Northern Italy and Greece (Drooger, 1954; De Mulder, 1975) evidences the primitive characters of *M. (Miogypsinoidea) bantamensis* from Si-a sample. It is confirmed that when the mean values of X decrease below $\bar{X} = 11.3$, other parameters start to differentiate statistically in comparison with higher values of X (i.e. $\bar{X} = 12.60$).

In fact, when X values are lower than $\bar{X} = 11.3$, the means of γ and D_1 display a large statistic variability, specifically if compared with the $\bar{\gamma}$ in the Si-a population. The γ values approach values of about or less than $\bar{\gamma} = 100^\circ$, whereas the means of D_1 tend to values between 180-200 μ .

Except for some uncertainties noted by De Mulder (1975), both the above mentioned French samples and the material from Greece yielded *M. (Miogypsinoidea) bantamensis* in association with specimens of *Miogypsina* s.s.; if the absence or extreme rarity of the latter taxon in the Si-a sample should

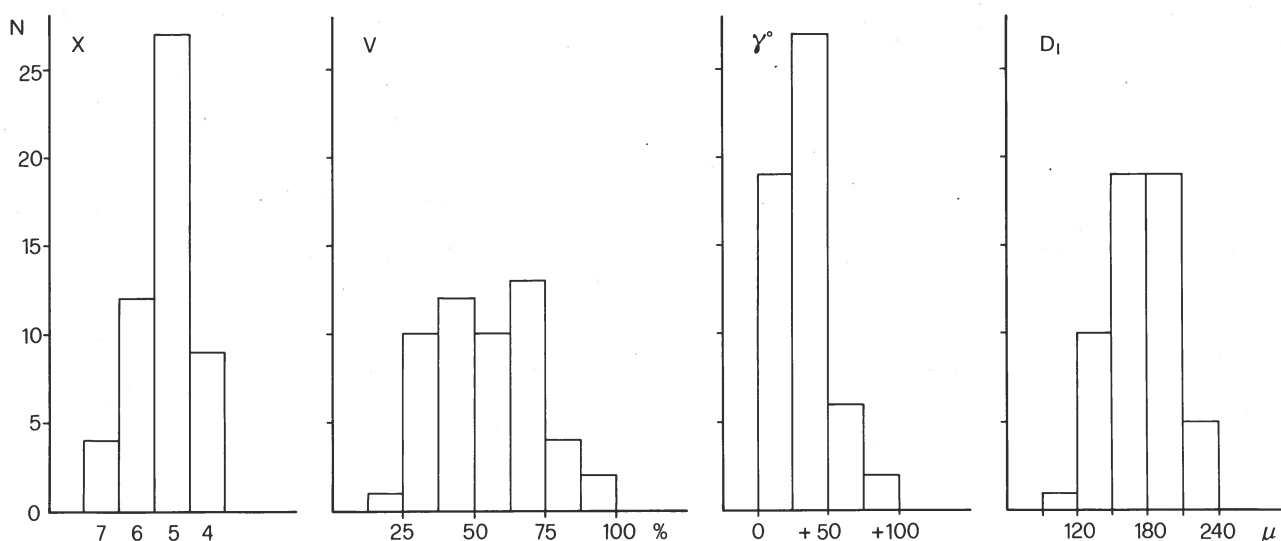
be confirmed by further analysis, the late development of *Miogypsina* s.s. in the Sardinia area may be considered a local event.

Spiral chambers surrounding the deuteroconch and surrounding the protoconch, both originated from the single primary auxiliary chamber of the main spiral, are present in numerous specimens; moreover the two spirals cross each other above the deuteroconch (Pl. 1, figs. 2, 6). Such a nepionic arrangement was also seen in *Miogypsina* (*M.*) *socini* Drooger (De Bock, 1977), in *Miogypsina (Miogypsinoidea) complanata* Schlumberger (Drooger *et al.*, 1955, pl. 1), in the American species *Miogypsina (Miolepidocyclina) bronnimanni* Drooger and *M. (Miolepidocyclina) ecuadorensis* Tan Sin Hok (Drooger, 1952, pl. 1), and in *M. (Miolepidocyclina) burdigalensis* (Gumbel) from Cameroon (Kupper, 1960, pl. 7). The opinion of De Bock (1977, pag. 14) that such characteristic is probably not only a local feature is here confirmed.

In AC 5 sample, the *Miogypsina* assemblage includes specimens provided with a more complex nepionic arrangement, with a second PAC from which a second nepionic spiral develops on the protoconch (Pl. 2, figs. 1-5).

In the 54 specimens examined, the position of the embryonic and nepionic chambers is clearly peripheric close to the apex of the test (Pl. 2, figs. 1, 2). All the specimens possess lateral chambers, whereas the presence of a canal system was not observed.

Beside the differences in the numerical data as plotted in Tables 1 and 2, the AC 5 and Si-a assemblages are morphometrically clearly different, as resulted from their scattering in areas clearly separated in the diagram of Text-fig. 6.



Text-fig. 5 - Histograms showing the distributions of X, V, γ , and D_1 values per number of specimens of *Miogypsina (Miogypsina) intermedia* Drooger, Sample AC 5, Ales section.

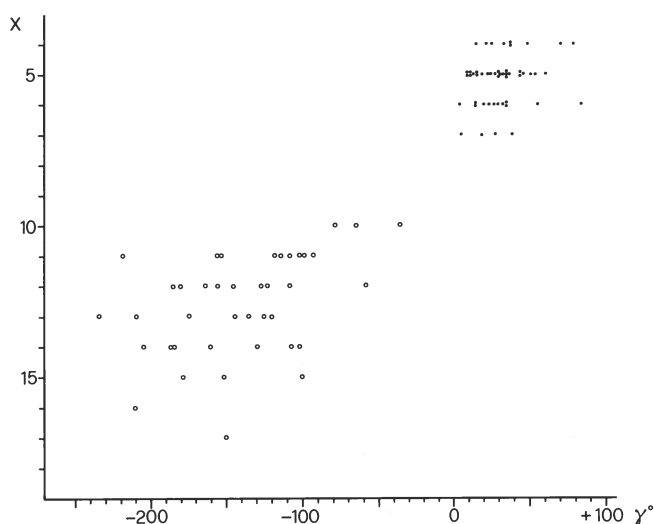
The very high mean value of V, which ranges from 45 to 70%, and the reduced mean number of chambers of the main nepionic spiral (less than 7) associated with a positive mean value of γ , would indicate parameters typical of *M. (Miogypsina) intermedia* Drooger (Drooger, 1952, p. 35; Schuttenhelm, 1976, p. 65).

The assemblage is heterogeneous, due to the presence of specimens belonging to one or more stocks at a lower evolutionary stage. That is confirmed by the distributional patterns represented in the histograms of Text-fig. 5: while for X and γ the distributions appear unimodal, for D_1 there is not a single maximum of frequency, whereas V is clearly bimodally distributed.

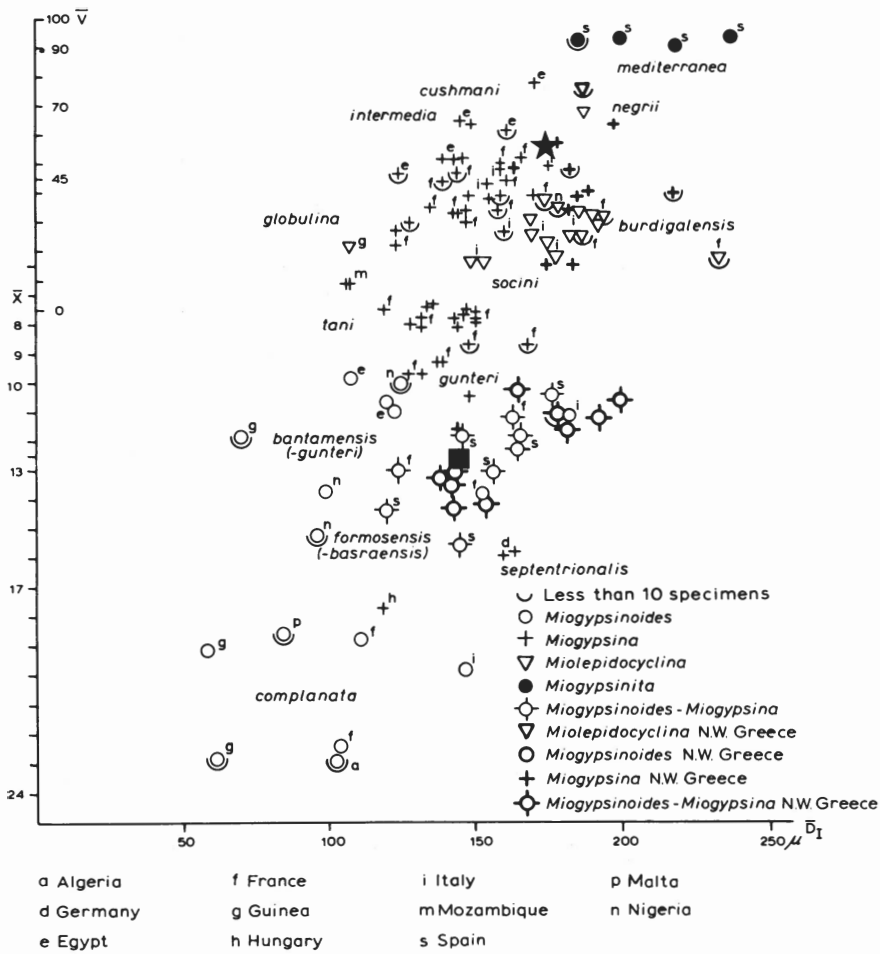
A second maximum of frequency is due to specimens with values of V ranging between 37.5-50%, which may relate to the presence of an evolutive stock referable to *M. (M.) globulina* (Michelotti), for which mean values of V ranging between 0-45% are estimated, associated with \bar{X} less than 7, and γ positive (Drooger, 1952, pag. 54; Drooger & Socin, 1959).

The comparison with the mean values of populations attributed to *Miogypsina (M.) intermedia* in literature (see a summary in Schiavinotto, 1979, tab. 11; 1984, tab. 2), shows that *M. intermedia* from AC 5 sample displays an evolutionary stage among the most advanced found till now, with \bar{X} and \bar{V} clearly further progressed with respect to that calculated in the populations from Southwestern France (Drooger *et al.*, 1955), Northern Italy (Schuttenhelm, 1976), and from central-southern Apennines (Schiavinotto, 1979, 1984).

Disregarding the data related to the supposed reworked stock, the evolutionary degree of the AC 5 population would be consistent with that already observed on Sardinian material by Smit (1974): all the values of \bar{V} are above 55% and up to 59.4% in SD 9 sample, which latter percentage represents one of the maximum values observed till now in *M. intermedia*, exceeded only by the data ($\bar{V} = 63\%$) obtained by De Mulder (1975) in the DM 140 and DM 669 assemblages from the Levkas Island section and Playa Peninsula (Greece) respectively.



Text-fig. 6 - Scatter diagram showing the relationship between X_{II} and γ values in *Miogypsina* from Samples Si-a (°) AC 5 (·).



Text-fig. 7 - Diagram showing the relationship between the mean diameter of protoconch (\bar{D}_1) and the $\bar{X}-\bar{V}$ scale values in Miogypsinid assemblages from Europe and Africa (after De Mulder, 1975); the mean values related to the Sardinian assemblages (Samples Si-a = ■ and AC 5 = ★) are also plotted.

For evidencing at first sight the evolutionary stage of Sardinian miogypsinids in comparison with other Mediterranean lineages, the \bar{X} , \bar{V} - \bar{D}_1 mean values derived from both Si-a and AC 5 materials were plotted in the diagram constructed by De Mulder (1975) on the basis of previous measurements on European as well as African species (Drooger & Raju, 1973) (see Text-fig. 7).

The mean values from sample Si-a drop in the field of the *bantamensis-gunteri* assemblages as reconstructed on the basis of the Spain, France, and Italian materials. The mean values from sample AC 5 drop within the mean values of *M. intermedia* inferred from material from France, Italy and Egypt; on the other hand they are clearly separated from the Balearic Island forms which were referred to the subgenus *Miogypsinita* by Drooger (1952, 1963, 1964). Thus, the Miogypsinidae from Sardinia represent only two short evolutionary stages of the much longer-ranging evolutionary lineages recognised not only in Italy but also around the Mediterranean area. This picture may be improved if further researches will confirm the

occurrence of the stages *M. complanata* and *M. gunteri* as reported by Cherchi & Montadert (1982).

PALEOGEOGRAPHIC AND STRATIGRAPHIC REMARKS

As previously reported, the Miogypsinidae from the AC 5 and Si-a samples belong to two phylogenetic stages chronologically very distant. It seems possible that further biometric researches will integrate our knowledge at least on the main lineage of the Mediterranean Miogypsinidae, starting from *M. (Miogypsinoides) complanata* up to *M. (M.) intermedia*.

Several evolutionary stages of the Mediterranean lineage seem missing in Sardinia, while in other Italian areas the same lineage assumes peculiar aspects, such as the development from *M. (M.) gunteri*, via *M. (M.) socini* Drooger, of representatives of the subgenus *Miolepidocyclus* (Drooger, 1954, 1963; Schuttenhelm, 1976; De Bock, 1977).

The fragmentary record of Miogypsinidae in Sardinia may reflect only temporary environmental con-

ditions suitable for their life during the Oligo-Miocene rifting phase in Sardinia. According to the succession of Miocene events reported by Cherchi & Montadert (1982a, b), the forms of a lower to medium degree of neopionic acceleration would have met rather unstable ecological conditions at the time of the sin-rift events (Late Oligocene-Aquitainian); this evolutionary stage is missing in Sardinia.

Post-rifting conditions were more stable, then a more developed neopionic stages such as *M. (M.) intermedia* could settle.

The absence in Sardinia of representatives of the end members of the Mediterranean Miogypsinidae lineage, such as *M. (M.) cushmani* Vaughan and *M. (Miogypsinita) mediterranea* Brönnimann, which however occur in the Balearic Islands (Drooger, 1963, 1964), Morocco (Brönnimann, 1940; Drooger, 1954b) and Algeria (Drooger & Magné, 1959), is supposed to be related to the opening of the Balearic Basin by Early Miocene (Cita, 1973, p. 109), which acted as a barrier. Sardinia became isolated and further faunal migrations from the Balearic Islands were prevented.

About the stratigraphic position of Sardinia Miogypsinids, only the youngest assemblage from sample AC 5 could be correlated directly to planktonic foraminiferal zonation scheme. In fact, they co-occur with planktonic foraminifera attributable to the *Globigerinoides altiapturus-Catapsydrax dissimilis* subzone of Early Miocene age (see Iaccarino *et al.*, this volume).

Planktonic foraminifera associated with the oldest Miogypsinids (sample Si-a) are too rare and poorly diagnostic for being attributable to a specific zone. According to the available correlations between Blow's planktonic foraminiferal zones and evolutionary stages of Mediterranean Miogypsinidae (see Drooger, 1963; De Mulder, 1975; Schuttenhelm, 1976), *M. (Miogypsinoides) bantamensis* might occur from the upper part of Zone N3 to part of Zone N4. Because of the primitive evolutionary stage of the *M. (Miogypsinoides) bantamensis* from Si-a, the Sardinian assemblage is supposed either to be not younger than an early Zone N4, or to have an Early to Middle Aquitainian age as similar assemblages described and surely dated by De Bock (1976).

According to the literature, *M. (Miogypsinina) intermedia* would range from middle Zone N6 through most of Zone N7 (De Mulder, 1975), or from late Zone N5 to early Zone N6 (Schuttenhelm, 1976). Because the evolutionary stage of the Sardinian *M. (Miogypsinina) intermedia* is more advanced than that of the assemblages from Piedmont Basin studied by Schuttenhelm (1976), an attribution to middle-late Zone N6 of the *M. (Miogypsinina) intermedia* studied here seems the most likely. The age suggested above is in agreement with the age inferred from the asso-

ciated planktonic foraminifera (see Iaccarino *et al.*, this volume), whereas it is much younger than that based on calcareous nannofossils (see Guide Book of the 19th Micropaleontological Colloquium).

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